metastable molecules, kinetic ions, etc., considers that there are no direct grounds for assuming the existence of compound ion formation except in the case of H_3+.

Using a mass-spectrograph of the Dempster type. it has been found that N_2H+ is produced abundantly when a mixture of N_2 and H_2 is bombarded with electrons. The accompanying graph shows the type of curve obtained in $N_2 + 5H_2$ at a total pressure of about 8×10^{-3} mm. From the intensity-pressure curve it appears that N_2H+ owes its origin to N_2+ and not to H_2+, and from the ionization function curve, that the reaction starts at the ionization potential of N_2.

Since compound ions of higher and lower mass were found in only very small quantities, it may be concluded that the formation of N_2H+ is only the first stage in the production of NH_3. The second stage presumably takes place at the walls in the presence of atomic hydrogen, in agreement with the results of Mochan and Gelbert[2].

The probability of the formation of N_2H+ is even higher than that of H_3+. Thus the ratio N_2H+/N_2+ is 4·3 times the ratio H_3+/H_2+ in that part of the pressure range which is free from selective absorption effects.

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[1] Lunt, *Trans. Far. Soc.*, **32**, 1691 (1936).
[2] Mochan and Gelbert, *Acta Phys. chim.*, **7**, 767 (1937).

Connexion between Electromagnetic and Neutrino Fields

As previously stated, one arrives at the formulation of specific 'coherence' (parallel motion) of two neutrino particles forming a photon, if both neutrino mass μ and neutrino 'charge' ε (non-electromagnetic) are put equal to zero but their relation to one another is kept constant[1], $\left(\frac{\varepsilon}{\mu} = \pi\sqrt{\frac{2c^3}{\hbar}}\right)$.

Developing the consequent neutrino theory of light, one must now establish the expressions connecting all components of the electro-magnetic field $\Phi_{\mu\mu^1}$ with neutrino wave functions ψ.

All requirements (that is, Maxwell's equations and the commutation rules) are fulfilled if one defines the antisymmetric field tensor by the following equation :

$$\Phi_{\mu\mu^1} = i\varepsilon\left(S_v \frac{\partial}{\partial x_v}\right)^2 \square^{-1}\varphi + \alpha_\mu \varsigma_3 \alpha_{\mu^1}\varphi,$$

where $S_v\frac{\partial\varphi}{\partial x_v} = \psi$; α_μ, ς_s are Dirac matrices and (S_μ) is an auxiliary constant vector, the direction of which corresponds to the definite choice of gauge for electromagnetic potentials[2].

From the neutrino wave function we can further construct two scalars defined by the formula :

$$\Phi = \varepsilon\ S_v\frac{\partial}{\partial x_v}\ \square^{-1}\varphi + S_\mu\beta_\mu\varphi,$$

where (1) $\beta_\mu = \alpha_\mu$ and (2) $\beta_\mu = \varsigma_1\alpha_\mu$.

These latter quantities are connected with the longitudinal component of the electromagnetic field.

The above relations yield Coulomb's law for the static case, if the distance between interacting electrons is less than $h/\mu c$, so that Maxwell's electrodynamics is limited from this point of view on the side of very great wave-lengths, which magnitudes depend from the mass of neutrino.

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[1] Sokolow, A., NATURE, **140**, 810 (1937).
[2] Sokolow, A., "On the Neutrino Theory of Light (3)", *Phys. Z. Sovjetunion*, in the press.

IN Jordan's form of the neutrino theory of light[1], the emission of a photon appears as the absorption and re-emission of a neutrino, or the simultaneous emission of a neutrino and an antineutrino, with identical directions. If the energy E and the momentum $\mathbf{p}$ transferred in the process are related by the equation

$$E = c|\mathbf{p}|,$$

as required by the usual theory, the mass of the neutrino must be assumed zero.

The angular momentum of a photon, in the direction of propagation, is either $\hbar$ or $-\hbar$. Assuming the neutrino to have spin $\frac{1}{2}\hbar$, this implies that the neutrino reverses its spin in the first kind of process, and that in the second kind the two particles have parallel spins.

From the mathematical point of view, the aim of the theory is to express the photon amplitudes, satisfying the commutation relations of the Bose-Einstein statistics, in terms of the neutrino amplitudes, satisfying the commutation relations of the Fermi-Dirac statistics, in a manner consistent with these physical assumptions. This can be shown to be impossible. The impossibility arises from the contradictory requirements of the conservation of angular momentum and the commutation relations. Certain pairs of two-rowed matrices occur, which by the first condition are required to be of the form

$$\begin{pmatrix} 0 & a \\ b & 0 \end{pmatrix}, \begin{pmatrix} 0 & -ia \\ ib & 0 \end{pmatrix};$$

the second condition requires that a and b should be different from zero and that the matrices should commute with one another, and this is easily seen to be impossible. No special form for the Hamiltonian function of the neutrinos need be assumed. A more detailed account has just appeared in the *Proceedings of the Royal Society of London*[2].

The three-dimensional neutrino theory proposed by Kronig[3], which at first seemed to offer a complete solution of the problem, is seen, on closer inspection, not to be invariant against changes of co-ordinates. It also violates the conservation law for angular momentum.

This result does not apply to the theory of Sokolow (cf. previous letter). The main difference between the theories of Sokolow and Jordan is in the mass of the neutrino. In the former it is essential that the rest-mass, however small, should be finite, whereas in the latter it is zero. It seems, if the neutrino theory is to be retained, that some deviation from Jordan's hypothesis, such as Sokolow's, must be tried.

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[1] Jordan, P., *Z. Phys.*, **93**, 464 (1935).
[2] Pryce, M. H. L., *Proc. Roy. Soc. A*, **165**, 247 (1938).
[3] Kronig, R. de L., *Physica*, **3**, 1120 (1936).